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## Method for isolating and purifying grass pollen allergens

The invention relates to a method for the rapid and effective isolation and purification of five allergens from groups 1, 2, 3, 10 and 13 from grass pollen. The natural raw material used for the allergen purification is the pollen of sweet grasses, such as, for example, of *Phleum pratense*. The purification is based on a novel combination of hydrophobic interaction chromatography, gel filtration and cation exchange chromatography. The proteins obtained in this way can be used for improved diagnostics of pollen allergies and for pharmaceutical preparations for the therapy of pollen-allergy diseases.

Type 1 allergies are of worldwide importance. Up to 20% of the population in industrialised countries suffers from complaints such as allergic rhinitis, conjunctivitis or bronchial asthma, which are caused by allergens present in the air (aeroallergens), which are released by various sources, such as plants, mites, cats or dogs. Up to 40% of these type 1 allergy sufferers in turn exhibit specific IgE reactivity in the case of grass pollen allergens (Freidhoff et al., 1986, J Allergy Clin Immunol 78, 1190-201).

The substances which trigger type 1 allergy are proteins, glycoproteins or polypeptides. After uptake via the mucous membranes, these allergens react with the IgE molecules bonded to the surface of mast cells in sensitised persons. If two or more IgE molecules link up with one another through an allergen, this results in the secretion of mediators (for example histamine, prostaglandins) and cytokines by the effector cell and thus in the corresponding clinical symptoms.

Depending on the relative frequency of the allergy sufferers having IgE antibodies against certain allergens, a distinction is made between major and minor allergens. In the case of timothy grass (*Phleum pratense*), Phl p 1 (Petersen et al., 1993, J. Allergy Clin. Immunol. 92, 789-796),

Phl p 5 (Matthiesen and Löwenstein, 1991, Clin. Exp. Allergy 21, 297-307; Petersen et al., 1992), Phl p 6 (Petersen et al., 1995, Int. Arch. Allergy Immunol. 108, 49-54) and Phl p 2/3 (Dolecek et al., 1993) have hitherto been characterised as major allergens and Phl p 4 (Löwenstein, 1978, Prog. Allergy 25, 1-62) and groups 10 and 11 from *Lolium perenne* (Ansari et al., 1987, J. Allergy Clin. Immunol. 80, 229-235) as minor allergens. In addition, a further high-molecular-weight major allergen that has been named Phl p 13 has recently been described. The group 1 and 13 allergens are glycosylated.

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In connection with the present invention, allergy groups 1, 2, 3, 10 and 13 are of particular importance. Established purification methods of the natural allergens are based on isolation of individual proteins in each case. By means of affinity chromatography using specific antibodies, group 1 allergens from *Lolium perenne* (Boutin et al., 1996, Int. Arch. Allergy Immunol. 112, 218-225) and *Phleum pratense* (Grobe et al., 1999, Eur. J. Biochem. 263, 33-40), for example, have been purified hitherto. This method is of limited capacity and is carried out using an extreme pH, with the consequence that it is not guaranteed that the native conformation can be obtained. Other methods are based on various multi-stage sequences of chromatographic steps. Individual allergens, such as, for example, group 10 (Ansari et al., 1987, J Allergy Clin Immunol 80, 229-235) or group 3 (Ansari et al., 1989, Biochemistry 28, 8665-8670), are in each case obtained here. Other allergens are lost or cannot be prepared in pure form in these methods.

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DNA sequence data are available, inter alia, for Phl p 1 (Laffer et al., 1994, J. Allergy Clin. Immunol. 94, 1190-98; Petersen et al., 1995, J. Allergy Clin. Immunol. 95 (5), 987-994), Phl p 5 (Vrtala et al., 1993, J. Immunol. 151 (9), 4773-4781), Phl p 6 (Petersen et al., 1995, Int. Arch. Allergy Immunol. 108 (1), 55-59) and Phl p 2 (Dolecek et al., 1993, FEBS 335 (3), 299-304). With the aid of cDNA sequences, it is possible to produce recombinant allergens

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which can be used in diagnostics and therapy (Scheiner and Kraft, 1995, Allergy 50, 384-391).

5 A classical approach to effective therapeutic treatment of allergies is specific immunotherapy or hyposensitisation (Fiebig, 1995, Allergo J. 4 (6), 336-339; Bousquet et al., 1998, J. Allergy Clin Immunol. 102 (4), 558-562). In these methods, the patient is injected subcutaneously with natural allergen extracts in increasing doses. However, this method entails the risk of allergic reactions or even anaphylactic shock. In order to minimise these  
10 risks, innovative preparations in the form of allergoids are employed. These are chemically modified allergen extracts which have significantly reduced IgE reactivity, but identical T-cell reactivity compared with the untreated extract (Fiebig, 1995, Allergo J. 4 (7), 377-382).

15 A greater degree of therapy optimisation would be possible with highly purified allergens. Defined cocktails from natural allergens are able to supersede the previous extracts since the latter, in addition to the various allergens, contain a relatively large number of immunogenic, but non-allergenic accompanying proteins which are not necessary for the specific  
20 immunotherapy. The use of allergen cocktails also enables the preparation of patient-specific allergen mixtures corresponding to the sensitisation spectrum. Realistic perspectives which could result in safe hyposensitisation with high-purity natural allergens are offered by modified allergens in which IgE epitopes are destroyed by irreversible modification of the secondary and tertiary structure without impairing the T-cell epitopes which are  
25 essential for the therapy.

The invention can likewise advantageously be used in in-vitro and in-vivo diagnostics of allergic illnesses, especially of pollinosis. To this end, the  
30 purified allergen groups are employed in established methods for the detection of IgE antibodies.

The invention relates to a biochemical purification method which results in the isolation of 4 major allergens and 1 minor allergen from aqueous short-time pollen extracts by an efficient three-stage purification. The natural raw material used is pollen of the Graminae, such as, for example, *Phleum*  
5 *pratense*, *Lolium perenne*, *Dactylis glomerata*, *Poa pratensis*, *Cynodon dactylon*, *Holcus lanatus*, inter alia. Fig. 1 shows the purification scheme of the 5 allergens mentioned from grass pollen extracts. The allergen names Phl p 1 to Phl p 13 correspond to the names allergens 1 to 13 otherwise used in the text.

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The invention thus relates to a method for isolating essentially pure group 1, 2, 3, 10 and 13 grass allergens in which an aqueous extract of Graminae pollen is prepared from, and the soluble constituents are subjected to hydrophobic interaction chromatography, a gel filtration step and, if desired,  
15 cation exchanger chromatography.

In accordance with the invention, it is also possible to carry out a plurality of steps of one type of chromatography, but in general the method is so effective that one separation step is sufficient in each case.

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The method is particularly suitable for isolating said allergens from the pollen of the species *Phleum pratense*, *Lolium perenne*, *Dactylis glomerata*, *Festuca pratensis*, *Holcus lanatus*, *Poa pratensis*, *Secale cereale*.

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In a preferred embodiment, the extraction is carried out by means of tris/HCl-buffered aqueous solution. However, it is also possible to employ, in accordance with the invention, other known aqueous buffer solutions.

30 For the purification of the said allergens, the soluble constituents of the extract are employed. To this end, the extract is centrifuged for from 3 to 8 minutes, preferably 5 minutes, at from 18,000 to 30,000 x g, and the super-

natant is taken for further purification. Alternatively, the insoluble constituents can be separated off by other methods, for example by filtration.

The first chromatographic purification step is carried out by means of  
5 hydrophobic interaction chromatography, for example on Sepharose®. In this, a large number of impurities are immobilised on the support, while the desired allergens are located in the fraction passing through the column. Corresponding other support materials can likewise be employed.

10 The invention thus relates to a corresponding method in which the group 1, 2, 3, 10 and 13 grass allergens are separated off from other constituents by means of hydrophobic interaction chromatography.

In the subsequent purification step, the grass allergens are separated into  
15 three fractions, with groups 1 and 13 each representing one fraction and groups 2, 3 and 10 representing the third fraction. The invention thus relates in particular to a method in which the group 1 and 13 allergens are obtained in separate fractions by a subsequent gel filtration step and are separated off from the group 2, 3 and 10 allergens.

20 The latter can then be separated from one another in accordance with the invention by a subsequent chromatography step via a cation exchanger. The invention therefore relates to a method in which the group 2, 3 and 10 allergens obtained after the gel filtration step are separated from one  
25 another by subsequent cation exchange chromatography.

The said allergens, which are known per se, are identified either via their known, different physical, chemical, biological or immunological properties, in particular by means of isoelectric focusing, UV absorption measure-  
30 ments, SDS-PAGE and specific antibodies. These methods and techniques are known and have been described in general terms.

The yield of the allergens obtained in accordance with the invention is 0.5 – 1.5%, based on the originally employed total protein of the grass pollen.

- The invention also serves to improve in-vivo and in-vitro diagnostics as part of identification of the patient-specific sensitisation spectrum which resolves allergen components. The invention thus relates to methods for the in-vivo and in-vitro diagnosis of pollen allergies using the allergens obtained in accordance with Claims 1 to 6.
- 10 The invention likewise serves to prepare improved preparations for specific immunotherapy of grass pollen allergies, which is achieved by separating off extract constituents which are immunogenic, but are irrelevant for the therapy. It is furthermore possible, through chemical reaction of the purified allergens, to obtain an allergoid preparation. The invention thus also relates
- 15 to a pharmaceutical preparation which comprises one or more allergens obtained by the method according to the invention and, if desired, corresponding assistants and excipients.

The method is described in detail below:

- 20 The purification of the natural allergens from timothy grass pollen is carried out in a three-step process (see Fig. 1). After aqueous extraction with tris/HCl-buffered solution (20 mM tris/HCl, 1 mM EDTA, pH 8.0) of pollen for 30 minutes, the extract is separated by centrifugation, preferably at
- 25 20,000 x g for five minutes. The tris/HCl-buffered (20 mM tris/HCl, 1 mM EDTA, pH 8.0) supernatant is treated with 1 M ammonium sulfate and subsequently subjected to hydrophobic interaction chromatography (Phenyl-Sepharose High Performance, Pharmacia). A typical column is packed with from 50 to 100 ml of the support material and operated at a flow rate of
- 30 about 5 ml/min. The fraction passing through the column comprises exclusively the proteins of five allergen groups: group 1 (30-35 kDa), group 2 (11 kDa), group 3 (12 kDa), group 10 (13 kDa) and group 13 (55-60 kDa).

This is followed by a reduction in the volume, preferably by ultrafiltration or lyophilisation.

In a second step, the group 13 and 1 allergens are then separated from the  
5 low-molecular-weight allergens by gel filtration in accordance with their  
different molecular weights using Superdex® 75 prep grade (Pharmacia) or  
similar known support materials which are suitable for this purpose. The  
elution medium is preferably 50 mM ammonium hydrogencarbonate. The  
column is operated at a flow rate of about 5 ml/min. Three fractions are  
10 obtained which comprise allergens 1 and 13 (each separately) and 2, 3 and  
10 (in one fraction).

The low-molecular-weight group 2, 3 and 10 allergens, which were eluted  
together in the third fraction of the gel filtration, are separated from one  
15 another by means of cation exchange chromatography. To this end, the  
lyophilised sample is taken up in an aqueous buffer, preferably 20 mM  
phosphate buffer, pH 7.2, and applied to a cation exchanger column equili-  
brated with this buffer (for example Source S®). The fraction passing  
through the column contains the acidic allergen 2. The bound allergens 3  
20 and 10 are eluted one after the other over about 20 column volumes by  
means of a salt gradient from 0 to 500 mM NaCl. The low-molecular-weight  
allergen group is thus separated into its individual allergens. Other cation  
exchanger materials can also be employed in accordance with the inven-  
tion.

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By means of the method according to the invention that is provided and  
which is distinguished by the specific sequence of the chromatography  
steps and the choice of chromatography media, the present invention thus  
facilitates a highly scalable production method for the isolation of a plurality  
30 of high-purity, natural grass allergens which is not labour-intensive or time-  
consuming and which can be implemented technologically. Since the purifi-  
cation methods used are very gentle for proteins, their conformations and

antigeneity are retained. This is a prerequisite for successful diagnostics of allergic illnesses.